Risk Management on Hyperion:
Consultant, Industry, and NASA Perspectives

Dr. Edmund H. Conrow, CMC, CPCM, PMP, Consultant
Mr. Stephen L. Carman, TRW Hyperion Project Manager
Dr. Bryant Cramer, NASA GSFC New Millennium Program Implementation Manager

1.0 New Millennium Program Overview

1.1 Earth-Observing Missions

The New Millennium Program (NMP) was founded in 1994 at the Jet Propulsion Laboratory. The purpose of the NMP is to flight-validate revolutionary new technologies that will lower the cost and risk, shorten the schedule, and enhance the performance of future science missions. Initially, the NMP was established within the Office of Space Science at NASA Headquarters. However, the Office of Earth Science soon became interested and became a partner in April 1995. It was agreed that each Office would sponsor a separate series of missions and they would share the results.

The series of missions sponsored by the Office of Earth Science is known as Earth-observing missions and three such missions have been thus far approved. The first Earth-observing mission (EO-1) was approved in March 1996 and assigned to the Goddard Space Flight Center. The EO-1 mission deals with a suite of three new land imaging instruments and several new spacecraft technologies that address a Landsat follow-on capability. This mission will launch in November 2000 and one of its instruments, Hyperion, is discussed in detail in the remainder of this paper. The second Earth-observing mission (EO-2) was approved in December 1997 and assigned to the Marshall Space Flight Center. The EO-2 mission involved an Orbiter-based lidar system to measure tropospheric winds from space. Due to overruns in cost and schedule, this mission was canceled in September 1999. The third Earth-observing mission (EO-3) was approved in January 2000 and assigned to the Langley Research Center. The EO-3 mission involves a new instrument known as the Geosynchronous Infrared Fourier Transform Spectrometer. Launch is planned for October 2004.

1.2 Science Versus Technology Validation Missions

NMP missions flight-validate revolutionary new technologies. These missions are characterized by the use of validation plans. Each assigned new technology has a specific validation plan composed of two parts. The first part addresses a technical validation led by technologists and engineers to demonstrate that the technology is operating on-orbit as expected. Once this is completed, the second part involves a science validation wherein scientists demonstrate the science for which the technology is ultimately intended. The results of both are then combined into the technology transfer documentation that will be used in the various workshops and other activities aimed at infusing this particular technology into future science missions.

2.0 EO-1 Program Overview

2.1 Programmatic Overview:

In 1992 Congress passed the Land Remote Sensing Policy Act wherein NASA is charged to ensure Landsat data continuity through the use of advanced technology. The NMP/EO-1 mission is specifically responsive to this Act. It contains a suite of three instruments that address a Landsat follow-on capability. The first is the Advanced Land Imager (ALI), a multispectral pushbroom imager with a band structure very similar to the current Landsat 7. This design represents a cost-effective replacement for conventional Landsat technology. The second instrument is the Hyperion, a grating-based hyperspectral imager with the same spatial resolution and spanning the same spectral coverage as the ALI. The third instrument is an Atmospheric Corrector that views the same swath width as Landsat 7 and provides correction for the intervening atmosphere for the other instruments. To facilitate inter-instrument comparisons, these three instruments simultaneously view the same target on the ground. Paired-scene comparisons with Landsat 7 will be accomplished by flying along the Landsat 7 ground track within one minute behind Landsat 7.

2.2 EO-1 Technologies and NMP Technology Categories:

The EO-1 technologies are depicted in Figure 1. These technologies are divided into three categories. Category I technologies are mandatory and the mission will be delayed or re-structured to properly flight-validate these technologies. Category II technologies are important but risky in terms of their maturity such that a conventional technology is carried in parallel should the new technology not mature as required for the mission. Category III technologies are flight opportunities. They are designed with interfaces such that their absence or failure cannot adversely affect the successful flight-validation of the Category I or II technologies.

The Advanced Land Imager (ALI) is a ten-band multispectral pushbroom imager of 30 m spatial resolution with spectral coverage from 0.4 through 2.5 μ. The band structure is very similar to that of Landsat 7. The swath width is designed to be 185 km but only 36 km is active in the ALI. The ALI incorporates three new technologies. The first is the multispectral imaging capability wherein the filter strips are located directly over the detector arrays. The second involves wide field reflective optics (15°). The third is silicon carbide optics; the ALI contains the largest silicon carbide mirrors flown to date. Relative to the current Landsat 7, the ALI represents a four-fold reduction in mass, power, and volume while achieving greater than a four-fold increase in the signal-to-noise ratio. It also serves as a calibration testbed to improve absolute radiometric calibration. This instrument is the only Category I technology on the EO-1 mission.

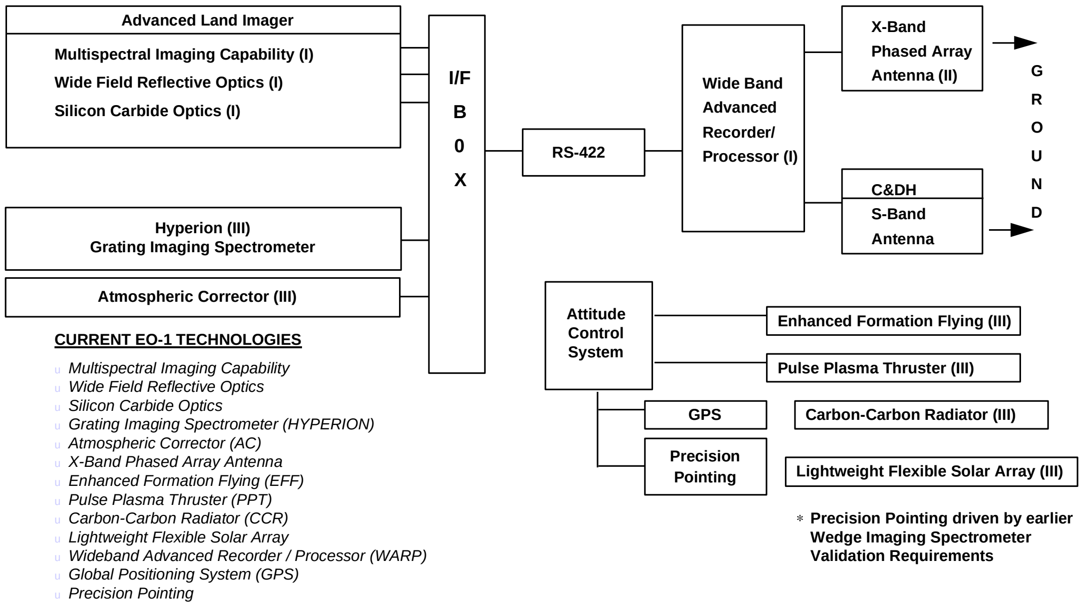

Figure 1. EO-1 Technologies

The second instrument is the Hyperion, a 220–band grating-based hyperspectral imager of 30 m spatial resolution, 7.5 km swath width, spectral resolution of 10 nm, and continuous spectral coverage from 0.4 through 2.5 µ. Hyperspectral imagery offers greater spectral resolution to better examine the fine detail of moderate resolution land imagery. During the EO-1 mission, this new capability will demonstrate backward compatibility with traditional Landsat imagery. Hyperion is a Category III technology. This instrument will be discussed in greater detail throughout the remainder of this paper.

The third instrument is the Atmospheric Corrector. It is a wedge-based imaging spectrometer of spatial resolution of 250 m, swath width of 185 km, continuous spectral coverage from 0.9 through 1.6 µ, and variable spectral resolution from 3 nm (at 0.9 µ) through 9 nm (at 1.6 µ) divided into 256 bands. This instrument corrects for water vapor and aerosols in the intervening atmosphere for the other two instruments. Due to the proximity to Landsat 7, it can also provide atmospheric correction to Landsat 7 imagery. It too is a Category III technology.

There are five spacecraft technologies that are also applicable to a Landsat follow-on capability. The first is an X-Band Phased Array Antenna that is the only Category II technology on the EO-1 mission. The others include Enhanced Formation Flying, a Pulse Plasma Thruster, a Carbon-Carbon Radiator, and a Lightweight Flexible Solar Array. These are all Category III technologies.

Lastly, there are three technologies that had to be "stretched" to accommodate the flight-validation of the above technologies. These include a Wide-band Advanced Recorder Processor to simultaneously ingest the high data rates of the three instruments, Hemispheric Resonating Gyroscopes to economically achieve precision pointing, and the Global Positioning System to assist in autonomous position determination.

3.0 Hyperion Program Overview

3.1 Hyperion Programmatic Overview

The Hyperion project was conceived by NASA GSFC to solve a problem they encountered in the development of the Earth Observer One (EO-1) spacecraft, the first of the earth observing missions in their New Millennium Program. The problem occurred when the grating imaging spectrometer (GIS) and wedge imaging spectrometer (WIS) could not be completed as planned, and NASA had to terminate the contracts. This left a significant hole in the planned scientific validation of the Advanced Land Imager (ALI), the primary instrument aboard the EO-1 spacecraft.

TRW Space and Technology Division had delivered a similar hyperspectral imager for a previous NASA mission (Lewis), and spare hardware from that development project was proposed as the basis for quickly fabricating a replacement for the GIS. NASA agreed with the idea, but required the instrument to be completed in less than half the time (12 months) that would normally be required for such a development, in order for EO-1 to meet its planned launch date.

To complicate matters, the scope of the project grew when studies of the effort required to integrate Hyperion into the ALI telescope assembly would require so much time that it threatened the scheduled EO-1 launch. Instead of integrating directly into ALI as had been planned for the original GIS, it was agreed that Hyperion should be designed as a stand-alone instrument so that it could be directly mounted on the spacecraft. This meant adding a telescope assembly, the associated motorized aperture door, and the supporting structure. Now a significantly more complex instrument (with perhaps a four year development period) had to be built *in the same 12 months.*

Fortunately, a spare set of partially processed telescope mirrors from another TRW instrument was available at the subcontractor (SSG) to expedite delivery of the telescope and spectrometer opto-mechanical subsystem. This telescope assembly was delivered on time is just six months, enabling Hyperion to be delivered to EO-1 a week *ahead* of schedule.

But the early Hyperion delivery would not have happened without the use of a comprehensive risk management process--this was a major factor contributing to the success of the project. In fact, NASA had insisted on a rigorous risk management process because they felt that poor risk management had led to the failure of the previous WIS and GIS projects.

3.2 Hyperion Technology

The Hyperion instrument provides a new class of earth observation data for improved Earth surface characterization. Hyperion is a complex hyperspectral imager that provides a pushbroom-type image of the earth's surface with 30-meter spatial resolution over a 7.5 km swath and 220 contiguous spectral channels from 0.4 to 2.5 microns in wavelength. Spectral bandwidth of each channel is 10 nm.

The instrument uses two focal plane arrays (FPAs), a visible near infrared (VNIR) and a short wavelength infrared (SWIR) FPA. A dichroic beam splitter separates the VNIR and SWIR beams, and a unique concave grating was developed to spectrally distribute the beam across each of the focal planes.

The SWIR FPA is actively cryo-cooled to 110 K using a TRW-developed pulse tube cooler. His sophisticated cooler is driven by its own electronics assembly, and has a large radiator on one end of the instrument for heat rejection. The instrument is will use the sun and moon for on-orbit radiometric calibration sources, and has two pairs of 4W calibration lamps that illuminate the inside surface of the aperture cover when it is closed, providing a repeatable check on responsivity stability.

The telescope metering structure is actively temperature controlled to 20 ±2C to minimize optical distortion. The entire optical portion of Hyperion is enclosed in an aluminum honeycomb enclosure that is supported on four titanium thermal isolators that mount on a shelf above the nadir-looking side of the spacecraft. A small harmonic drive with integral encoder moves the cover to three positions. The cover is normally closed and opens during image acquisition sequences (typically a few minutes). The cover can also be moved to the solar calibration position at an approximately 45° angle that reflects the sun off a diffuse white paint on the inside surface of the cover. The harmonic drive has sufficient spring retention that a separate cover release device is not required for launch.

A RS1773 fiber optic interface to the spacecraft communicates commands and housekeeping data from/to the spacecraft. Data is transmitted to the EO-1 solid state recorder using two parallel, redundant RS422 interfaces. The Hyperion electronics assembly (HEA) and the cryocooler electronics assembly (CEA) are mounted on the upper deck of the spacecraft, on a shelf separate about two meters from the from the Hyperion Sensor Assembly.

3.3 Hyperion Risk Management Requirements and Needs

Even though NASA needed a rigorous risk management process, the contractual language pertaining to risk management was short and simple. In fact, the only place risk management was mentioned in the Statement Of Work was a single reference in the systems engineering portion to "develop and implement a proactive Risk Management Plan." Hence, NASA provided the flexibility for the TRW team to implement whatever risk management process it chose, but closely monitored risk management implementation to make sure that it was being continually used (and not just prior to project reviews) and that it was effectively assisting the Hyperion development process.

Given that Hyperion was a very fast-paced project with about a 4:1 schedule compression a full-blown risk management program would never succeed. A major challenge then, was how sophisticated should the process be, and to what level should it be implemented on the project. Beyond the NASA requirement to develop the RMP, we had to implement the process and use it on a daily basis. Hence, aspects of a risk management process with marginal or limited use that might be justified on a project with a less-compressed schedule could not be afforded on Hyperion. It was also necessary to document the Hyperion risk management work in a timely fashion for both NASA and TRW to permit both to evaluate progress being made on the project. Yet the documentation could not be excessive given the limited resources available and the short turnaround times that existed to produce it. These were but some of the considerations that existed that were used to shape the risk management process on Hyperion.

4.0 Hyperion Risk Management Introduction

4.1 How Risk Management Was Implemented on Hyperion--the Process

The risk management consultant started about two months after initiation of the Hyperion development activity. This might seem unimportant on most projects, but given that the development phase of Hyperion was about six months (followed by six months of integration and test), this was a substantial gap in time. In addition, the risk management consultant was assigned to the Hyperion project about half-time. Hence, lost time could greatly multiply even in a week or so in terms of the work that needed to be completed, compared to many projects where a month or two would be an equivalent time-frame.

The first thing that the consultant did was to tailor the risk management process he had used on other projects to Hyperion. The primary consideration was how to devise and implement a comprehensive risk management process on a very fast-paced, high technology development project.

We used the Department of Defense (DoD) risk management process, as outlined in the Department of Defense, "Risk Management Guide for DoD Acquisition," Defense Acquisition University and Defense Systems Management College, First Edition, March 1998 (and Second Edition, May 1999) [1]. The risk management consultant had been an active participant in helping to develop this process for DoD, and performed numerous edits of the resulting "Risk Management Guide for DoD Acquisition." This risk management process includes risk planning, assessment (identification and analysis), handling, and monitoring steps with feedback from risk monitoring and documentation for all process steps as illustrated in Figure 2.

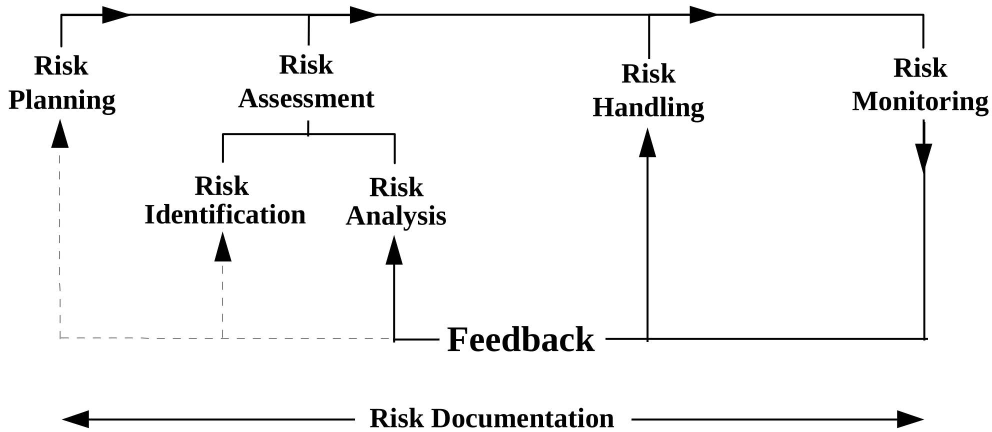

Figure 2. DoD Risk Management Process

Risk planning involves developing and documenting a systematic and comprehensive strategy and methods for identifying and analyzing risk issues, developing and implementing risk handling plans, monitoring risk issues to determine how they have changed, and documenting the overall risk management process.

Risk identification involves examining the program areas and each critical technical process to identify and document the associated risk issues.

Risk analysis involves examining each approved risk issue to refine the description of the risk, isolate the cause, and estimate the level of risk present.

Risk handling involves the identification, evaluation, selection, and implementation of strategies to reduce risk to an acceptable level given program objectives and resources.

Risk monitoring involves systematically tracking and evaluating the performance of risk handling actions.

Given the time constraints that existed on Hyperion, coupled with the daily engineering management meetings where risk issues were discussed, the one process step that was scaled back compared to what would normally be done on another project was risk monitoring. Here, risk monitoring was less formalized than would typically exist. Nevertheless, this is not to say that risk monitoring was not performed. For example, we formally updated the project schedule on a weekly basis and made adjustments as needed sometimes on a daily basis. Hence, planned vs actual schedule variations were very closely monitored--much more so than on many development projects. Earned value was also computed on the project and used to track cost performance (e.g., cost variance), but because the update was performed every two weeks, results sometimes lagged important development activities, again because of the very fast paced schedule.

One of the key risk management considerations for Hyperion was the development of the risk analysis methodology. Here, we needed to have a comprehensive methodology that covered the anticipated risk areas, but one that could be routinely used by the entire project team, and not just limited to the risk management consultant every several months. For example, ordinal scales were used to estimate the probability and consequence of occurrence risk terms, yet had to be tailored to fit Hyperion. One particular easy to understand case is that the consequence of occurrence scale included definitions associated with the schedule component relating to months that had to be converted to weeks to be appropriate and meaningful for Hyperion.

We settled on six probability scales for hardware items, five probability scales for software items and two probability scales for integration items (one for hardware/hardware and one for hardware/software). We also used three consequence of occurrence scales; namely cost, performance, and schedule; for each item evaluated. No mathematical operations were performed on results from the ordinal scales because this will lead to erroneous results [2]. Instead, we developed a risk mapping matrix that mapped probability and consequence of occurrence scores into five risk levels (low, low medium, medium, medium high, and high). Hence, for a hardware risk issue there were 6 (probability) times 3 (consequence) or 18 resulting risk scores. We documented each risk score, but only reported the highest risk level for each of the three consequence of occurrence terms. Hence, the 18 hardware risk scores were reduced to three summary risk scores (one each for cost, performance, and schedule), by taking the maximum of the six probability:consequence pairs for the cost consequence term, six probability:consequence pairs for the performance consequence term, and six probability:consequence pairs for the schedule consequence term. While this may not be a perfect reporting scheme, it is nevertheless a conservative and mathematically correct approach since the maximum risk level is reported in each case and no mathematical operations are performed (e.g., averaging) on the data obtained from the ordinal scales.

The RMP was developed and tailored from the RMP the risk management consultant had written for a large TRW DoD program, experience on a wide variety of other programs, plus key risk management documentation from DoD and other organizations. This permitted an advanced draft of the very substantial RMP (~90 pages) to be delivered about two weeks after the risk management consultant started to work on Hyperion. (Without the prior, relevant experience, it would have taken roughly four months to have written such an RMP.) One of the keys to making the RMP, as well as the risk management process, work on Hyperion was to continually ask the questions “what is the benefit/cost of doing this particular activity, and does it make sense?” For example, because there was neither a need nor a requirement to perform a cost risk analysis, this methodology was not included on Hyperion. The resulting RMP documented key inputs, tools and techniques, and outputs associated with the risk identification, analysis, and handling process steps (with, as previously discussed, less emphasis on formal risk monitoring).

One of key considerations in developing the RMP was the nature of the risk evaluations (identification, analysis, and handling) that had to be performed along with the frequency of performing them. On a typical project, a comprehensive risk evaluation might be performed once a year (or less frequently) and updated quarterly (or less frequently). However, for Hyperion this was clearly unsatisfactory given the highly compressed and fast paced schedule that existed. To aid the risk evaluation process, documentation was specifically developed for risk identification (about 1/2 page), risk analysis (two pages), and risk handling (one page). Key questions asked during the development of the documentation included: “will it be effective and does it make sense?” This philosophy was used to both screen and tailor the items included on each piece of documentation.

For example, one very helpful documentation-related item was the conversion from paper risk identification, analysis, and handling forms to a word processing format following the first program-wide risk assessment by Mr. Carman’s assistant, Ms. Margaret Dugan. This greatly assisted rapidly developing draft Risk Evaluation Reports (RERs), and permitted changes to be readily viewed and tracked through the use of the word processing revision mode. And in the spirit of how risk management was implemented on Hyperion, Ms. Dugan came up with the idea on her own initiative to make the risk document an easily edited form within the word processing program. This idea literally saved many man-weeks during the course of the project and permitted high quality reports to be prepared and delivered to NASA on a short turnaround basis.

After the draft RMP was completed, the TRW project manager, TRW deputy project manager for systems engineering (Dr. Paul Lee) and the risk management consultant decided to conduct an initial risk evaluation of a single candidate risk issue and present the results to the entire engineering management team for review. The rationale behind this approach was that if the project upper management and risk management consultant could not successfully use the process and document the results in a timely, cost effective manner, then team members would not likely use risk management principles in their daily activities, nor be enthusiastic about evaluating and updating risk issues.

The initial risk evaluation was performed on a hardware item--a transceiverless 1553 chip to a 1773 transceiver converter box. The key risk issue here was that: 1) a new 1773 transceiver design existed along with untested components, 2) special handling was needed for the fiber optics in the converter, and 3) a new configuration was needed to convert the 1773 to 1553 interface.

It took about four hours to complete the risk identification form, perform the risk analysis and document it, and develop a draft risk handling plan (RHP). While this was not “speedy,” the fact that this was the first time the process was tested, along with the fact that subsequent updates for a given risk issue would likely be performed much faster, the resulting time to perform the risk evaluation was not viewed as unacceptable. After the risk evaluation was completed, the TRW project manager briefed the Hyperion engineering management team on the results the very next day. (This included the focal point for developing the converter box.) The team critiqued the risk evaluation. While they suggested some minor changes to the risk identification and risk analysis results, they also concluded that the process was sound and could be applied to a variety of risk issues. Perhaps more importantly, this initial risk evaluation showed the team that the key project managers were: 1) personally involved in supporting risk management on Hyperion, 2) willing to accept constructive criticism from the project team and update results, and 3) recognized what it would take to perform the risk evaluations. Quite simply, the value of having the project manager and deputy project manager perform the first risk evaluation and brief the project team can not be understated--it was clearly a key to making risk management successful on Hyperion.

Shortly after this initial risk evaluation, the risk management consultant then gave a two hour training session to the engineering management team. This training session "stretched" all in attendance, and it was clear that the consultant would have to work with the entire team in order to perform the initial risk evaluation, plus the updates.

The initial risk evaluation was performed in September 1998, a matter of weeks after the risk management consultant was "brought on board" the project.

Several inputs were used to perform risk identification, including: 1) the project WBS, 2) the project budget, 3) the project schedule, 4) data collected from other projects, 5) NASA specified performance requirements, 6) information about key processes, and 7) the RMP (which, among other things, included key ground rules and assumptions associated with the project (e.g., all risk analyses are based upon *today's* state of the world, not a future projection). The risk management consultant met "one on one" with cognizant engineering personnel. The above inputs were used in conjunction with: 1) lessons learned from other projects, 2) brainstorming and interviewing key project personnel, and 3) risk review questions that served as indicators of potential risk issues to perform the risk identification. Risk identification forms were completed for candidate risk issues and forwarded to the Risk Management Board (RMB), chaired by the Hyperion project manager and also included the deputy project managers for systems engineering and operations, other key engineering management personnel, and the risk management consultant. Risk issues approved by the RMB were then analyzed very shortly thereafter to determine the level of risk present. For each approved risk issue, the risk management consultant met with the risk issue focal point (typically the responsible engineer for that item) "one on one" to perform the risk analysis, using the risk analysis methodology previously outlined, along with the RMP (including its ground rules and assumptions). After completing the risk analysis for each item and documenting it on the risk analysis form, a draft RHP was developed and also documented on its corresponding form. (We were careful in developing the RHPs to evaluate all four risk handling options (assumption, avoidance, control, and transfer) and not just "default" to the control (mitigation) option as commonly occurs.) After completion of the draft risk analysis and risk handling activities, the RMB convened, offered suggested changes that were incorporated into the risk analysis and handling forms, approved the results along with a prioritized list of risk issues (that were derived from the risk analysis methodology discussed above).

From the time that the risk management consultant started on Hyperion to when the first RER was completed totaled *six weeks*. This is extremely fast paced considering that the:

1) risk management process had to be tailored to Hyperion, 2) RMP had to be developed and approved, 3) training performed, 4) risk identification performed, 5) RMB approve candidate risk issues, 6) risk analysis and risk handling performed, 7) draft RER was written, and 8) final RER was completed approved. Normally, this level of work would take four to six months or longer on a typical DoD program, but given the short Hyperion schedule (six months each for development and integration and test), a longer period to implement risk management would have been of no value to Hyperion. This coupled with the support from the Hyperion project manager and deputy project manager and the experience of the risk management consultant led to the rapid implementation of risk management on the project.

Over the next several months the risk management consultant worked with project personnel on almost a daily basis--attending the daily engineering management meetings perhaps four days a week plus a variety of other interactions with project personnel. Five more risk evaluation updates were completed and documented in the RER during the course of the project--a total of six risk evaluations were performed and documented in seven months. This is a highly unusual level of both performing and documenting risk identification, analysis, and handling on a high technology project, all the more so given that the risk management consultant worked on the project roughly half-time and the time needed to perform the risk evaluations decreased as project personnel became more familiar with the risk management process and associated documentation. More importantly, as risk management "success stories" occurred on the project, this encouraged project personnel to incorporate risk management into their decision making process for design trades, evaluating test results, developing workarounds, etc.

Near the end of the development cycle (December 1998), a decision was made by the project manager and risk management consultant to implement a Monte Carlo schedule risk analysis to estimate the probability of shipping the instrument vs potential delivery dates. This was important on Hyperion because there was both an incentive for early delivery and a penalty for late delivery (as discussed in Section 6.2). Two simulation packages were evaluated that were add-ins to the project scheduling package used on Hyperion. Both simulation add-ins either crashed or gave erroneous results using the Hyperion schedule. Given this unacceptable situation, the risk management consultant worked with scheduling personnel and vendors at the two companies that developed and marketed the simulation packages to understand the cause of the problems and what workarounds might exist. Within a week the source of the problem had been identified--it involved linking tasks across separate project files--something that neither simulation package could properly integrate with. The workaround developed by one TRW scheduler (Mr. David Moreno) was to create a standalone schedule file incorporating all needed tasks for the integration and assembly (I&A) module. This was the most important remaining schedule module on the project since it incorporated the final set of tasks (I&A) as well as those on the program's schedule critical path.

With this workaround in place both schedule risk analysis add-ins now worked properly and one was chosen and used to perform a simulation of the schedule about three times a month. (While the selected simulation package was slower to run and more complex than the one rejected, it offered much greater flexibility for distribution types, project schedule logic, and output reports. In the retrospect, the simpler, rejected package would not have likely yielded acceptable results.) This provided the project manager with a probabilistic estimate of the completion date and other key milestones. The risk management consultant worked with cognizant project I&A personnel to estimate probability distributions associated with key remaining activities. A key point here is that the consultant did not force project personnel to pick one of a small number of distribution types or a single distribution type, but worked with the technical experts to develop a suitable probability distribution. This led to a wide variety of distributions being incorporated into the simulation, including but not limited to: cumulative, histogram, and triangle distributions. (Note: some simulation packages do not permit the use of cumulative and histogram distributions, yet historical data was best matched by these types of distributions for a number of key activities.) These probability distributions were entered, and the simulation typically run 1,500 iterations. As mentioned above, a key output of performing the Monte Carlo simulation was to develop a probabilistic estimate of the completion date and other key milestones that the project manager could use both within Hyperion, as well as to provide this information to higher level managers both within TRW and NASA.

4.2 How Risk Management Was Implemented on Hyperion--Organizationally

As mentioned in Section 4.1, daily engineering management meetings existed on the Hyperion project. This enabled a wide variety of technical and issues to be discussed on a daily basis, and workarounds developed for these issues often within the same day. A key to making the engineering management meetings work was the project manager encouraging and allocating time for each member of the team present to speak. This, together with an atmosphere that welcomed rather than condemned inputs, encouraged project personnel to discuss their progress as well as concerns. Simply stated, there was no “shoot the messenger” atmosphere on Hyperion. Risk management-related concerns were discussed by the project manager and risk management consultant, and all project personnel were encouraged to the extent reasonable think and discuss issues within a risk management framework. Thus, the daily engineering management meetings provided an effective framework for identifying candidate risk issues and evaluating progress on reducing risks to acceptable levels via RHPs being implemented.

The risk management consultant was effectively the risk manager on Hyperion, reporting directly to the TRW project manager. This level of responsibility, coupled with the reporting channel, sent a “positive signal” to other personnel on the project that risk management was an important consideration and viewed by both the project manager and deputy project manager as a key to success for Hyperion. The risk management consultant had a wide variety of responsibilities, including but not limited to: 1) development and update of the RMP; 2) development and implementation of the risk management process; 3) provided risk management training to project personnel; 4) worked with project personnel to perform risk assessments and develop draft RHPs; 5) provided generation, control and update of all risk assessments; 6) reviewed all risk management related documentation for delivery to the RMB; 7) assisted the RMB in performing detailed evaluation and documentation of risk issues, risk analysis results, and RHPs developed by project personnel; and 8) and developed risk management-related documents (e.g., RERs) and other material (e.g., briefings given to NASA and TRW personnel) for the project manager.

The RMB formally met only slightly more than once a month, but the RMB members were also participants in the daily engineering management meetings. Hence, when necessary, RMB-related decisions could be made on an "as needed basis" each day. This permitted rapidly identifying and approving new candidate risk issues (e.g., as in the case where an enhanced vibration load requirement was transferred to Hyperion from the spacecraft, which required a substantial redesign in a focal plane array support structure to prevent a vibration-induced failure). It also provided quick feedback on risk monitoring results, so that RHPs could be modified as needed and supporting resources could be allocated across RHPs and/or new resources added as necessary. Simply stated, having an RMB meeting once a month and management not considering risk-related activities between RMB meetings would have prevented a successful completion to Hyperion because of the extremely fast-paced project schedule. The daily engineering management meetings, coupled with all project personnel willing to consider risk management principles as part of their job function, greatly contributed to the Hyperion success. Having the "greatest" risk management process in the world will not really help a project if it is not used by both management and working-level personnel on a daily basis.

5.0 NASA Perspective and Lessons Learned

5.1 Support to EO-1 and NASA:

The EO-1 mission was twelve months past its Critical Design Review by the time that the decision was made to add the Hyperion instrument. It was therefore essential that TRW organize the Hyperion Project to confidently deliver the instrument on time so as to minimize the impact on the launch readiness date. To this end, TRW was requested to establish a robust risk management capability at the outset. TRW was also incentivized to deliver on time with a greater emphasis on schedule than on budget. This effort was highly successful. The Hyperion was delivered one week ahead of schedule and has since proven to be a very dependable instrument during spacecraft integration and testing.

5.2 Hyperion Risk Management Effectiveness:

From the NASA perspective, the risk management on the Hyperion Project is a model to be thoughtfully considered. The cost avoidance exceeded the investment in risk handling by many times. This is particularly true for the Hyperion Project and it is also true for the EO-1 Project. The money initially invested in risk management was truly well spent. The leadership of an experienced risk management consultant who implemented and took ownership of the process, an interested and supportive project manager, a knowledgeable and eager systems engineer, and a general willingness of the working-level engineers all combined to produce an outstanding result.

5.3 Application to Other NASA Programs:

The Hyperion Project clearly demonstrates the tangible benefits of an early implementation of robust risk management. In this case, TRW quickly recognized the importance of risk management and sought expert assistance. From the NASA perspective, TRW's willingness to seek expert assistance was the critical enabling first step. Aspects of the Hyperion Project that are potentially applicable to other NASA projects include the following:

1) Substantial cost avoidance attributable to robust risk management particularly when the available schedule is tightly constrained.

2) Value of an experienced risk management consultant to organize the effort and coach the participants in the project.

3) Willingness of the project to accept risk management as a mindset that permeates their daily activities.

5.4 Other Observations:

Not all risk management efforts will be this successful. In this case, an experienced risk management consultant encountered an almost ideal opportunity to demonstrate what might be accomplished. The cooperation and support of the Hyperion Project was essential. Whether this emanated from some perceived necessity or just curiosity may never be determined. In the end all of the participants came to complement each other in a very successful team effort. The Hyperion Project represents an outstanding example of contemporary risk management.

6.0 TRW Project Manager Perspective and Lessons Learned

6.1 Support to EO-1 and TRW

The Hyperion risk management process was TRW's first application of the new risk management methodology derived from DoD and other sources by the risk management consultant. By scaling the process from a large TRW program where he had developed a comprehensive RMP plus other programs, the consultant rapidly developed an effective risk management process, streamlined RMP and proposed them to NASA. NASA GSFC EO-1 project and JPL NMP project offices approved the process and we implemented it by the third month of the project--only a few weeks after the consultant began.

The ultimate success of Hyperion in delivering the hardware a week ahead of the very aggressive schedule drew a lot of management attention on the process at NASA as well as at TRW. Although certain aspects of the process remain proprietary, the general approach was briefed to many NASA centers, NASA Headquarters, and similar processes are now under development within NASA.

Within TRW, the Hyperion risk management process was featured in a new risk management workshop made available to all TRW personnel in the Redondo Beach, California facility. The workshop is taught by the Hyperion project manager and uses the Hyperion project experience as a case study. While the workshop was under development, many projects and proposal teams at TRW were briefed on the Hyperion risk management process, and several have implemented it with good success.

6.2 Hyperion Risk Management Effectiveness

The effectiveness of the Hyperion risk management process quickly became evident because of the relatively short duration of the project. Risk issues were retired within just a few months of decisions to pro-actively handle them. The team, who became more enthusiastic about detecting and handling risks when they saw the fruit of their earlier risk assessments, celebrated each success item that was retired. This attitude change fostered a risk-sensitive culture throughout the team, which was as an important element in achieving the short schedule.

For example, our initial risk assessment found that our subcontractor had contracted the task of building the dichroic beam splitter to a supplier who had never fabricated an interference filter with as many layers (about 50 to 60) and as broad a spectral range (visible through SWIR) as our design required. The interference filter was assessed to be a medium level risk and the fixed-price subcontractor was encouraged to find an alternate or parallel supplier. When the subcontractor said no, we contracted a supplier that we felt had more experience in this type of filter. About a week before the filter was to be integrated into the spectrometer, the initial source supplier called to say he was having difficulty meeting our specification, and wanted some relief on the requirements. We compared his filter performance to our requirements and found that the filter performance would significantly compromise the instrument performance, so we turned to our second supplier, who delivered filters that met our requirements just 3 days later, in time for integration. So we had a risk management celebration.

Similar stories repeated across the 18 risk issues identified during the Hyperion project. Any one of the risks that were averted, had they come to pass, would have impacted the project cost many times the cost of executing the risk management process. The Hyperion delivery schedule incentive/penalty was about $50,000/day. Any of the retired risks could have impacted the schedule, resulting in negative fee on the project. Hyperion final costs were within 1% of contract target cost, which was also enabled earning some incentive fee.

There were the unexpected problems too, that were not anticipated by the risk management process, but we were able to handle because of the good schedule position that effective risk management had provided. By February of 1999, the project plan indicated we would deliver Hyperion about five weeks ahead of the July 14 delivery date. Unexpected problems in vibration caused some significant erosion in the slack to delivery, but we still were able to deliver a week early.

6.3 Application to Other TRW Programs

As mentioned earlier, the Hyperion risk management process has been briefed to numerous programs at various stages of completion. Several proposals have featured tailored versions of this process, and several have successfully implemented the program in the year since Hyperion project delivered the instrument.

The first class to participate in the new Project Risk Management workshop that is based on the Hyperion experience is schedule for August 30, 2000. This expanded training provides an 8-hour, hands-on experience for participants to understand the process and practice its implementation on project scenarios derived from Hyperion.

6.4 Other Observations

For this fast-paced program where every project engineer felt the enormous pressure of a tight schedule, initial reception of the risk management process was less that enthusiastic. But because the project manager was directly involved in leading and implementing the process, the team gave it proper attention at the beginning, during the planing and during subsequent risk assessments and when developing and implementing RHPs. The project manager and project system engineer also supported training given by the risk management consultant.

Once RHPs were developed, they were integrated into the ongoing project schedule and statused on at least a weekly (sometimes daily) interval. Because they were obviously important to the project office as evidenced by the daily dialog, they became important to the team.

As risks were lowered and eventually retired over the following months of the project, the celebrations of lowered risks (no big party, often a round of “high fives,” or sometimes a cake) heightened our awareness of the power of the pro-active risk management process. The Hyperion team became a risk-sensitive team that took pride in identifying new risks, and finding appropriate risk handling strategies. Achieving this cultural change was a major, if not primary, key to succeeding in this challenging project.

7.0 Risk Management Consultant Perspective and Lessons Learned

7.1 Hyperion Risk Management Effectiveness

The risk management process developed and implemented on Hyperion was consistent with DoD and NASA best practices and best industry practices. Except for a somewhat informal risk monitoring process (due to schedule constraints discussed in Section 4.1), the remainder of the risk management process was as sophisticated if not more so than that routinely used on projects with life cycle costs in excess of $1 billion, and having an development period of four to eight years. This is in contrast to Hyperion, whose budget was < $20 million and was completed in about 12 months! Hence, a sophisticated, comprehensive risk management process can be developed and implemented on a very fast-paced, small budget project.

However, in order to do so, it is absolutely essential to have a very knowledgeable, experienced risk management practitioner (risk management consultant in this case), coupled with senior project management that are committed to implementing and personally using risk management on the project and in their daily decision making activities. This together with a supportive project atmosphere towards risk management sends a very positive signal to all project personnel that risk management is not only "OK" but it is very important to the success of the project. The value of leadership by example from the project manager can not be underestimated in the oftentimes struggle to effectively implement risk management on a project. Simply stated, you can have the "best" risk management process in the world, but if it is not being used on a continuous basis by project personnel, the resulting overall effectiveness will be quite low [3]. And often times the "atmosphere" on the project is not supportive for performing risk management--made all the more difficult on projects performed by organizations that do not have a strong history of effective risk management. In such cases it is crucial that the project manager or deputy project manager be a champion for risk management, along with having a skilled risk management practitioner to guide and implement the process [3].

In addition, the risk management consultant must be able to converse with working level engineers on technical issues. This is important for two reasons. First, it greatly improves the efficiency of the process; potentially saving considerable time in reducing the number of false starts, iterations needed to perform a risk analysis or develop an RHP, etc. Second, it provides the basis for mutual professional respect between the partys' which also enhances the effectiveness of the risk management process through encouraging project engineers to embrace risk management principles.

Similarly, the project manager (or deputy project manager) must be willing to learn about risk management and apply its principles in their daily decision making. It is one thing to talk about risk management and give "pep talks" to project personnel, and quite another thing to *practice* risk management. Yet for the project manager (or deputy project manager) to practice risk management, and doing it in an effective manner, is perhaps one of the most important keys to success if not the most important key to achieving effective risk management [3]. Too many times I have witnessed project managers who were either uninterested in practicing risk management or gave it "lip service." Well, working level personnel read those signals "loud and clear" and did not embrace risk management principles as part of their daily job function. The results was in many cases an ineffective risk management process that resulted in risk issues coming back to haunt the project as problems late in the development phase. Yet in most cases (e.g., except when a project re-baselining occurred) these issues could have been identified and handled much earlier in the project with far less cost and schedule impact. Simply stated, on many projects, the cost savings from one or maybe two major averted risk issues that impact the project late in the development phase will pay for most, if not all, of the risk management-related work during the entire course of the project! As the television commercial from some time ago said: "pay me now or pay me later," meaning perform adequate risk management now or have expensive workarounds later. It is your choice.

7.2 Possible Application to Other Programs

The risk management process developed and implemented on Hyperion can be applied to a wide variety of projects because it was consistent with DoD and NASA best practices and best industry practices. In fact, the only enhancement at the process-step level that should be considered and implemented is a more formal risk monitoring process.

But clearly, the risk management process must be tailored to the project, not the project to the risk management process (which can lead to a mismatch and an ineffective risk management process). For example, the risk analysis methodology, including ordinal probability and consequence of occurrence scales and the risk mapping matrix, may be at least somewhat different if used on another project because of the risk categories present, and because of differences in budget and schedule.

Several keys to success associated with the Hyperion risk management process that can be transferred to other projects include, but are not limited to: 1) having focused, formal risk planning is desirable prior to performing the initial risk assessment; 2) a comprehensive program-wide risk identification using the WBS and key processes to minimize the number of risk issues going undetected; and 3) the development of succinct, but telling RHPs, which helped identify implementation steps that otherwise would have been missed and provided insight into when backup risk handling strategies were desirable and when they should be implemented.

Key management involvement is absolutely essential for effective risk management. The success of risk management on Hyperion was largely driven by the desire and active participation of the project manager and deputy project manager in the risk management process. This provided a viable leadership example to project personnel instead of lip service that is quite common. On Hyperion, a culture shift occurred which included risk management as part of the daily decision making process by both management and working level personnel. This is very important, since a weak approach to implementing risk management will lead to an ineffective process. In addition, project personnel became increasingly committed to using risk management as evidence of risk management "successes" repeatedly solved risk issues and averted problems.

Finally, although details can not be provided for proprietary and security reasons, the risk management principles used on Hyperion have been successfully implemented on other projects.

7.3 Other Observations

As mentioned in Section 6.4, the initial reception to risk management was cool, while not hostile. Hence, both the project manager and the risk management consultant were "on trial" to some extent pertaining to risk management. Project personnel routinely watched us to see if we were "walking the walk, not just talking the talk." As the days went by on Hyperion and it became increasingly more evident that risk management was being practiced and it led to several surprisingly decisive successes (e.g., the dichroic beam splitter discussed in Section 3.2), project personnel appeared to go from tolerance to embracing risk management principles in their daily assignments. And in several cases project engineers mentioned this to me privately in a one-on-one setting. (One advantage on a short-duration project is that if you are performing risk management properly, "success stories" will occur in a timely manner. However, you are also "on trial"--if you do not perform risk management properly, the entire project team will see your failures.)

The fact that the risk management consultant could converse directly with project engineers on technical issues helped to make the implementation process more efficient, as well as the risk identification, analysis, and handling process more effective. In several cases it was the technical interaction between project engineers and the risk management consultant that resulted in identifying missing issues (risk identification) and steps in the subsequent RHPs (risk handling) that might otherwise have undetected for some time (as well as correcting risk analysis results). Yet without the project engineers having respect for the risk management consultant, independent of how "good" the risk management process was, their desire to embrace risk management and consider it in their daily activities would have been diminished.

A high complement paid to the risk management consultant on more than one occasion by NASA GSFC management was that risk management "saved the project." In effect, the excellent progress made on the project, coupled with a highly effective risk management process, convinced NASA senior management to continue funding Hyperion and not cancel it. This was despite the fact that Hyperion by all accounts was a very high risk project (mostly because of the 4:1 schedule compression and the short project schedule), and could have been canceled at several funding milestones during the course of its development.

One additional outcome of the Hyperion risk management process success was that the risk management consultant was hired by NASA as a consultant to help them more effectively implement risk management on other projects.

8.0 References

[1] Department of Defense, “Risk Management Guide for DoD Acquisition,” Defense Acquisition University and Defense Systems Management College, First Edition, March 1998 (and Second Edition, May 1999).

[2] Ibid., pp. 16-17.

[3] Edmund H. Conrow, “Effective Risk Management: Some Keys to Success,” American Institute of Aeronautics and Astronautics, Reston, VA, 2000, pp. 47-49.